Laser Stripping of Aerospace Materials with Closed-Loop, Color-Recognition Control

ASETS Defense 2009 Workshop

Sustainable Surface Engineering for Aerospace and Defense

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Laser Surface Preparation

Laser Ablation is the 21st Century Solution for Surface Cleaning and Surface Preparation:

- *Demonstrated Zero Reduction in Material Properties*
- *Negligible Environmental Impact and Abatement Costs*
- *Installable as Workcell in Existing Production Facilities*
- *Versatile Configurations with COTS–NDI Components*
- *Demonstrated Reliability and Maintainability*
- *True Closed-Loop Control Enables Manual or Robotic Positioning of Laser Workhead with Color Recognition*
- *Cost Competitive with Current Decoating Technologies*
- *The Only Laser Process that is FAA Approved for Commercial Aircraft*
- *Successful Applications with Aluminum, Titanium, Steel and Composite Materials*

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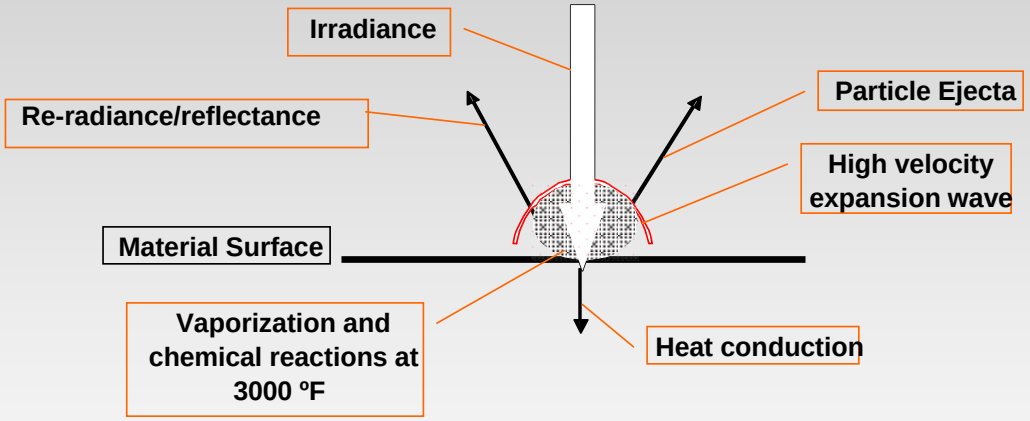
Photoablation Physics

Laser Ablation Process

- High-Intensity Radiant Heating (10-30 MW/cm^2)
- Very Short Duration (0.2 μsec),



- High Reflectance, so Heat Conduction is Small

  Time $_{Vaporization}$ << Pulse duration << Time $_{Conduction}$

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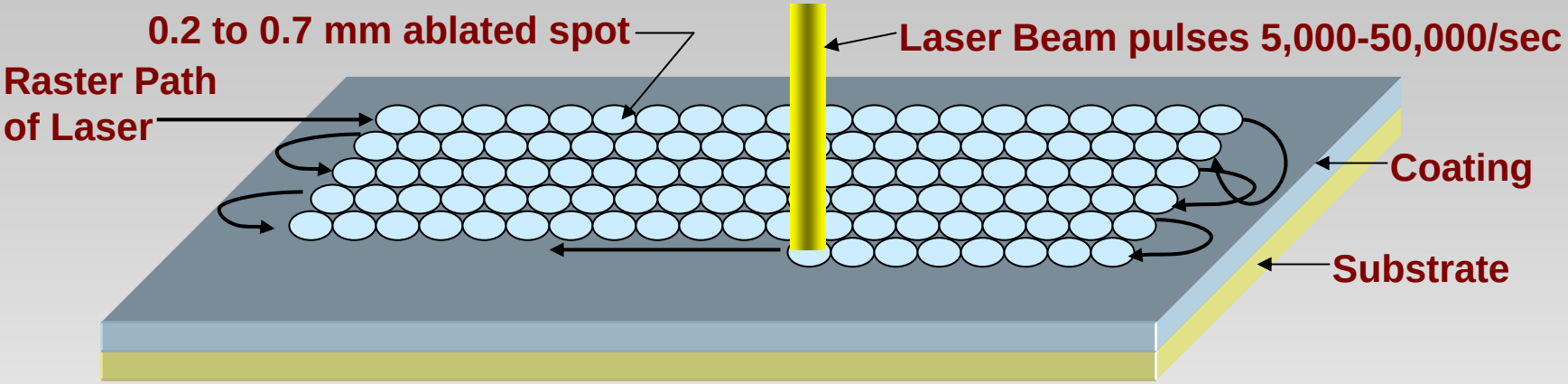
Surface Physics

Laser Scanning



- Coating removal from aerospace materials
  - Metal oxides and dust → Particulate ejecta
  - Oils and solvents → $H_2O + CO_2$
- Process Parameters Optimized to Clean and Deoxidize / Depassivate Substrate Surface

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Surface Physics

Photoablation-Induced Texture

2024-T3 Alclad

"Golf Ball" texture
0.7 mm dia. x
0.008 mm depth in
0.05 mm-thick clad
layer

- Laser Parameters can be controlled in order to achieve desired surface finish effects

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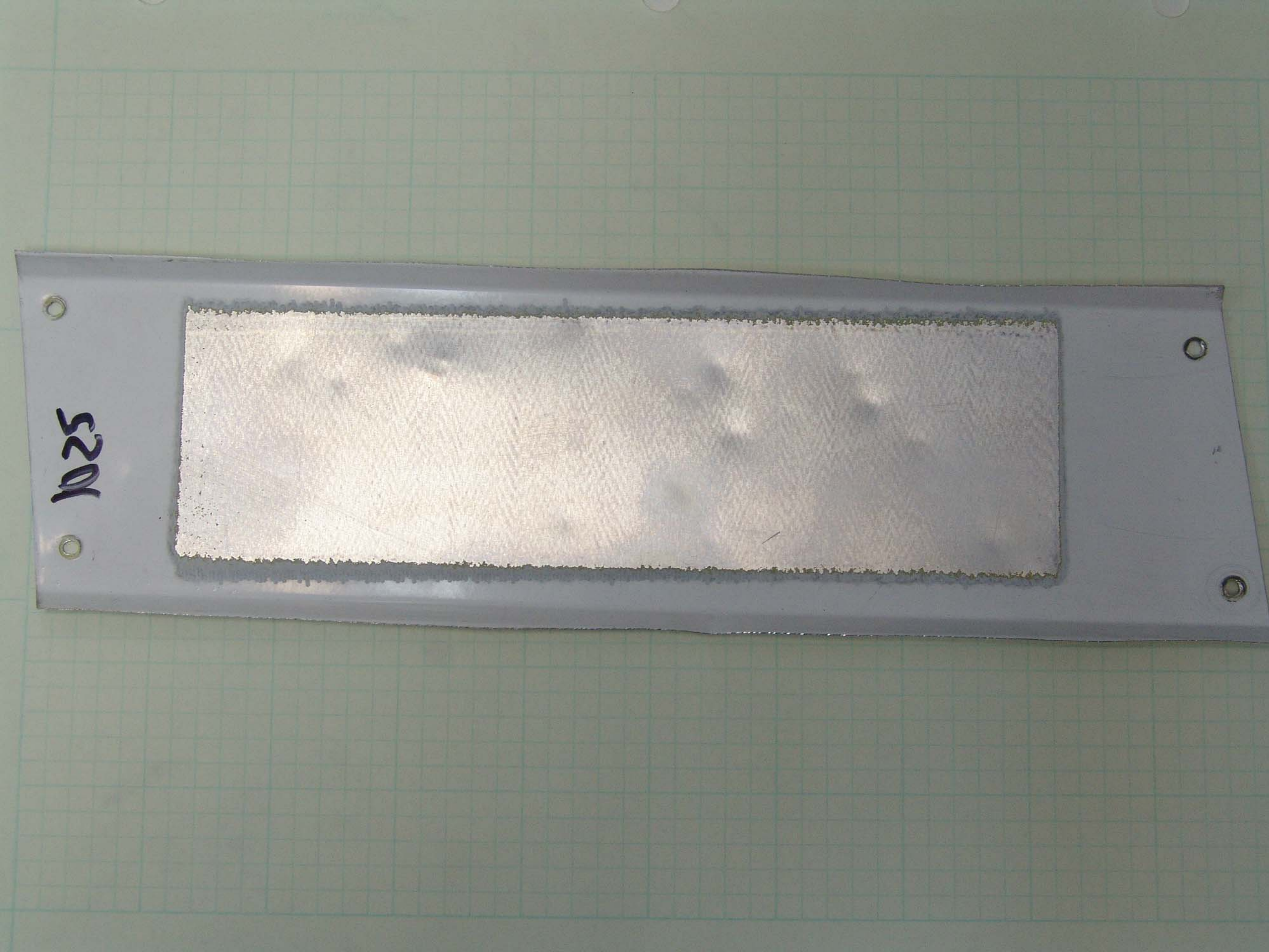
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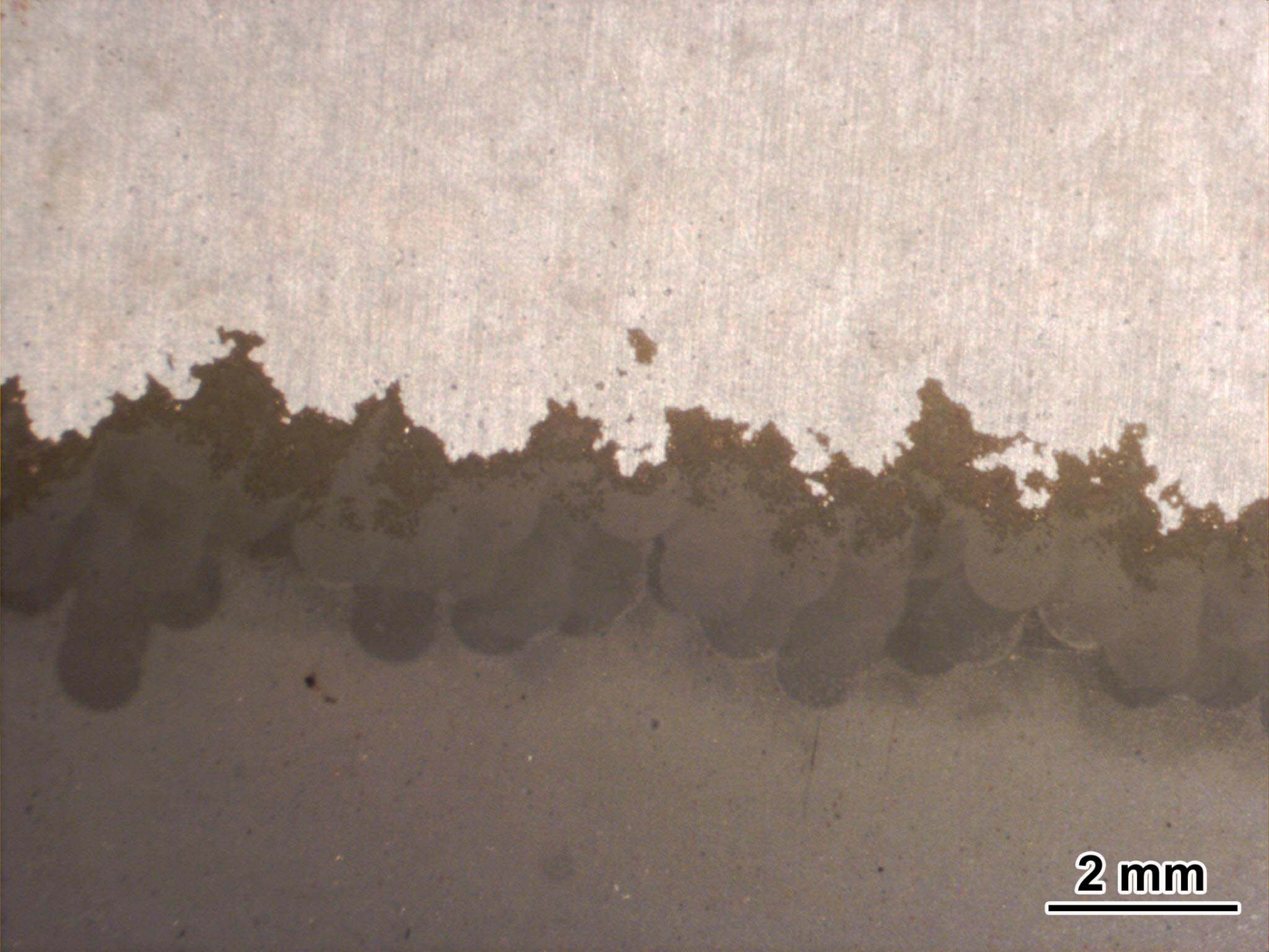
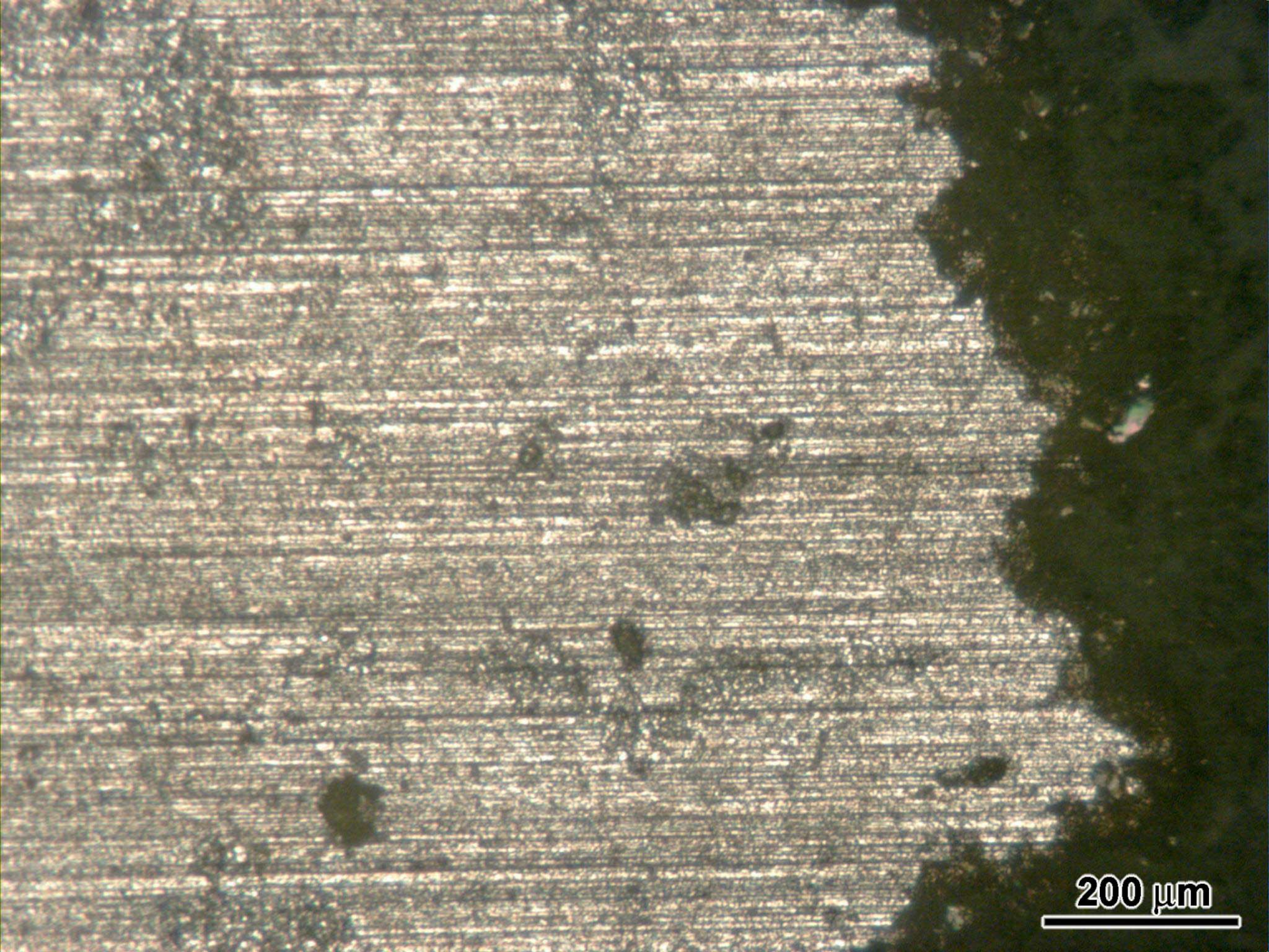
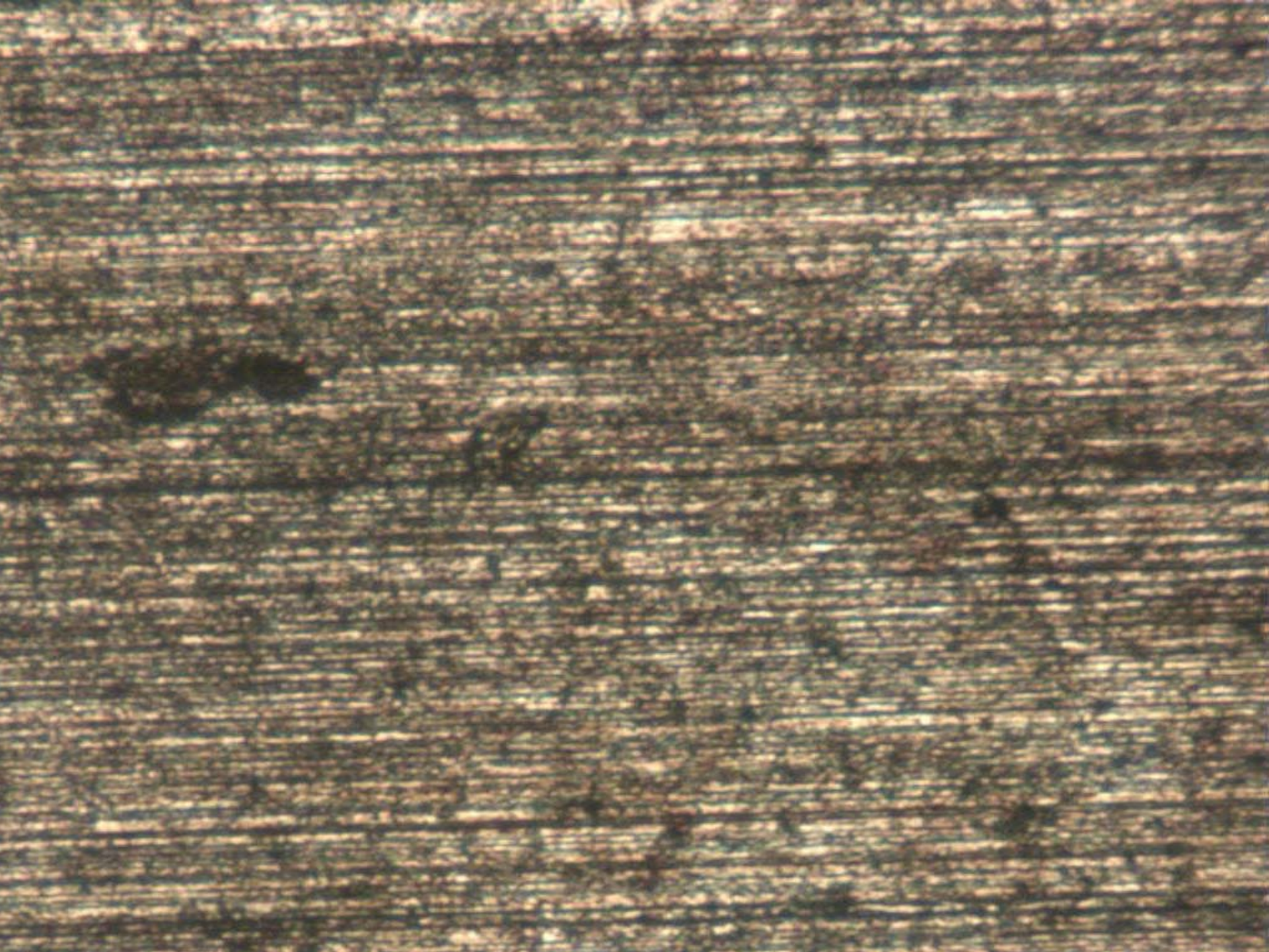
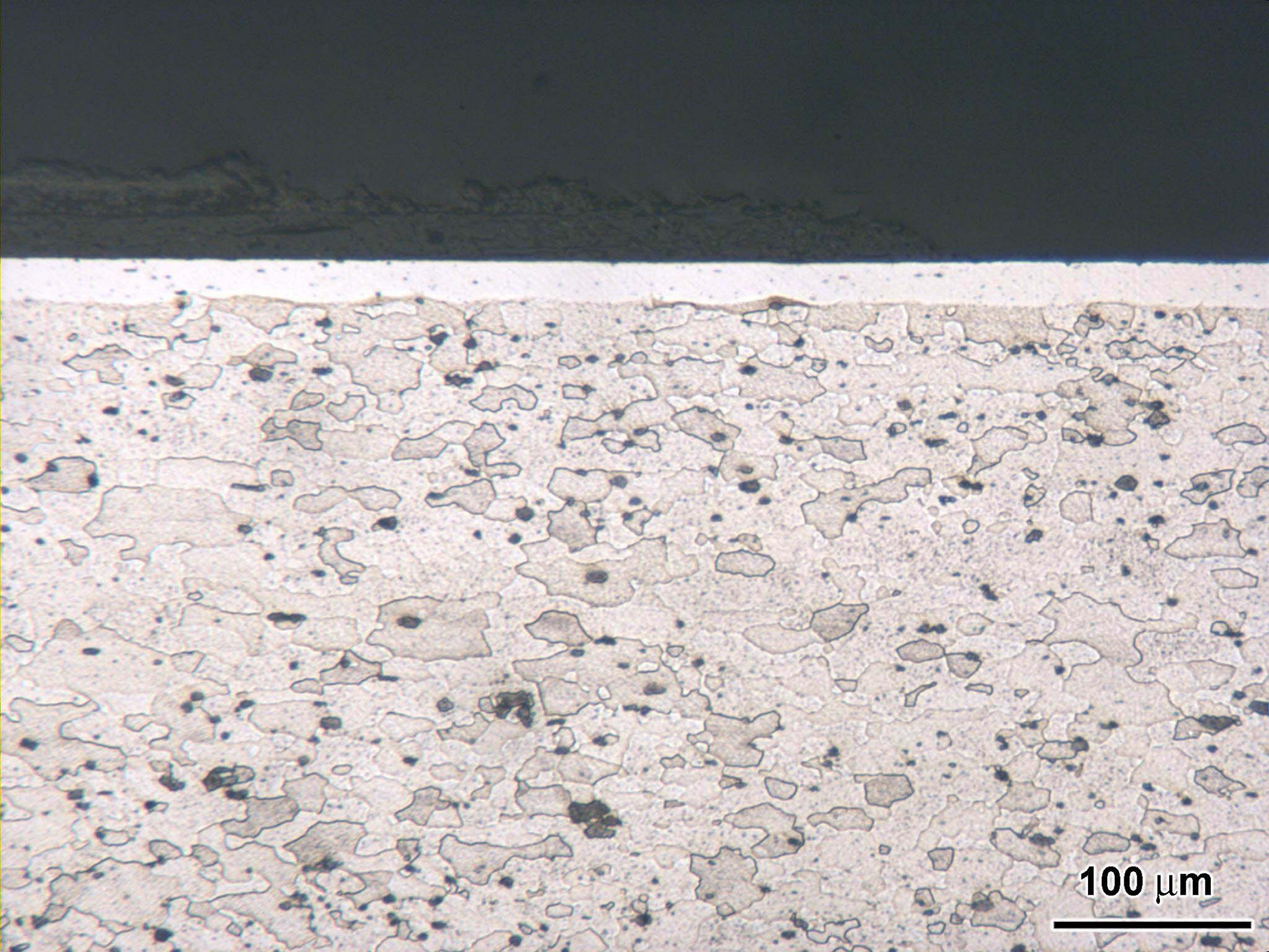
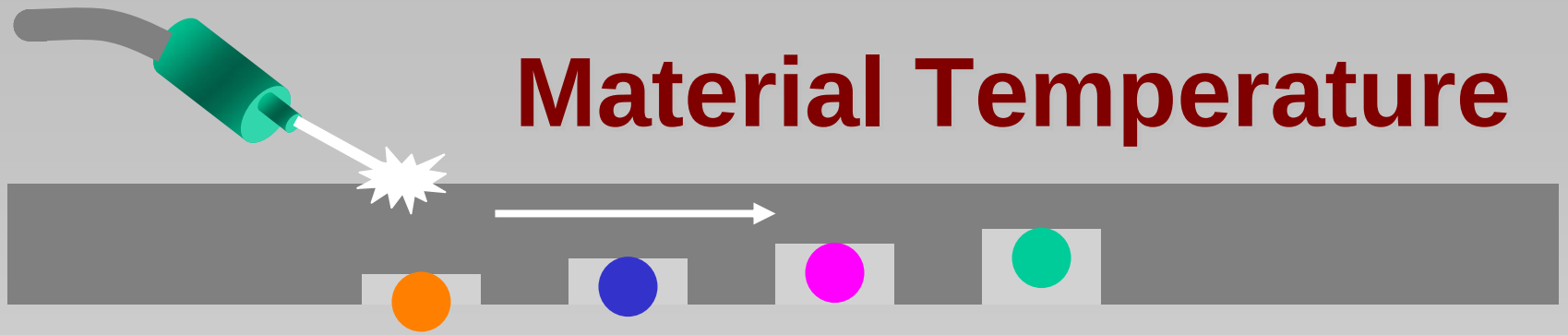

2 mm


200 µm

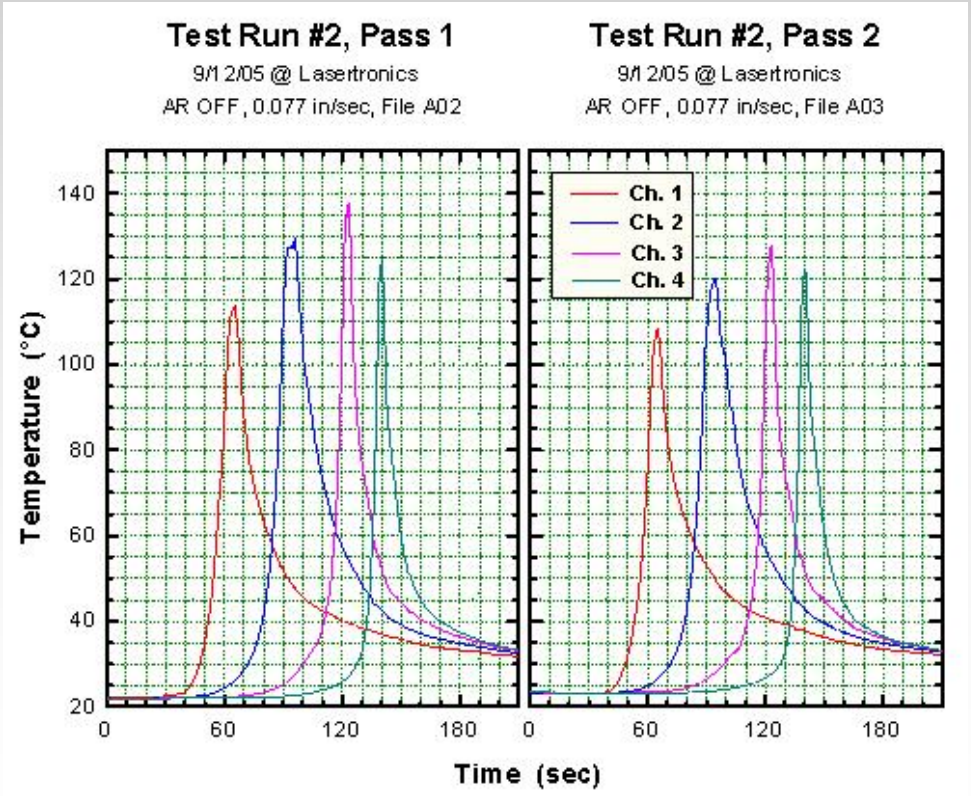



100 μm

Material Temperature



Channel 1 Channel 2 Channel 3 Channel 4



- Temperature data at 4 depths during paint removal from 2024-T3 Al Clad
- Peaks match laser traverse events
- Ch. 4 impacted by thermal mass of doubler plate

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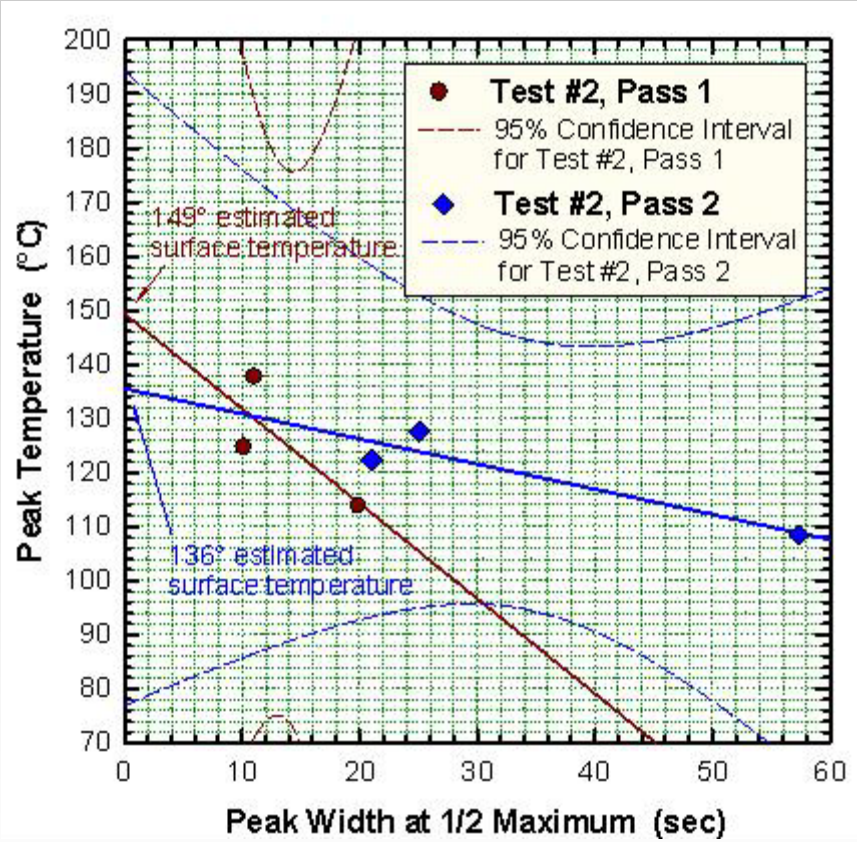
Surface Temperature Estimates

Well below reference values



2024-T3 References

Annealing Temp
412.7 °C (775 ° F)

Solution Temp
493.3 °C (920 ° F)

Aging Temp
190.5 ° C (375 ° F)
for 8 -16 hours

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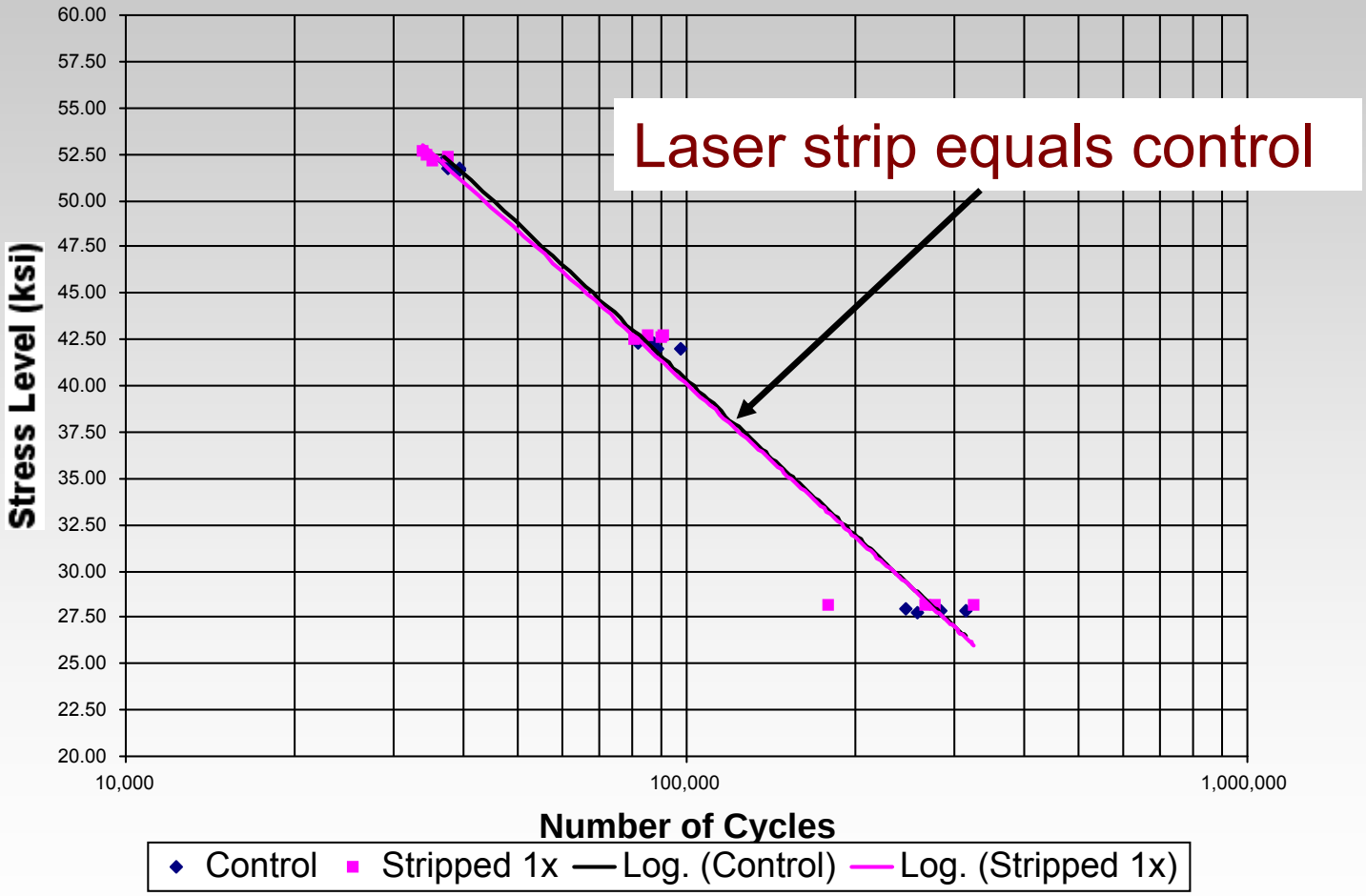
S-N Fatigue Testing

GLC Fatigue Life Test for FAA - 2024-T3 Al-Clad



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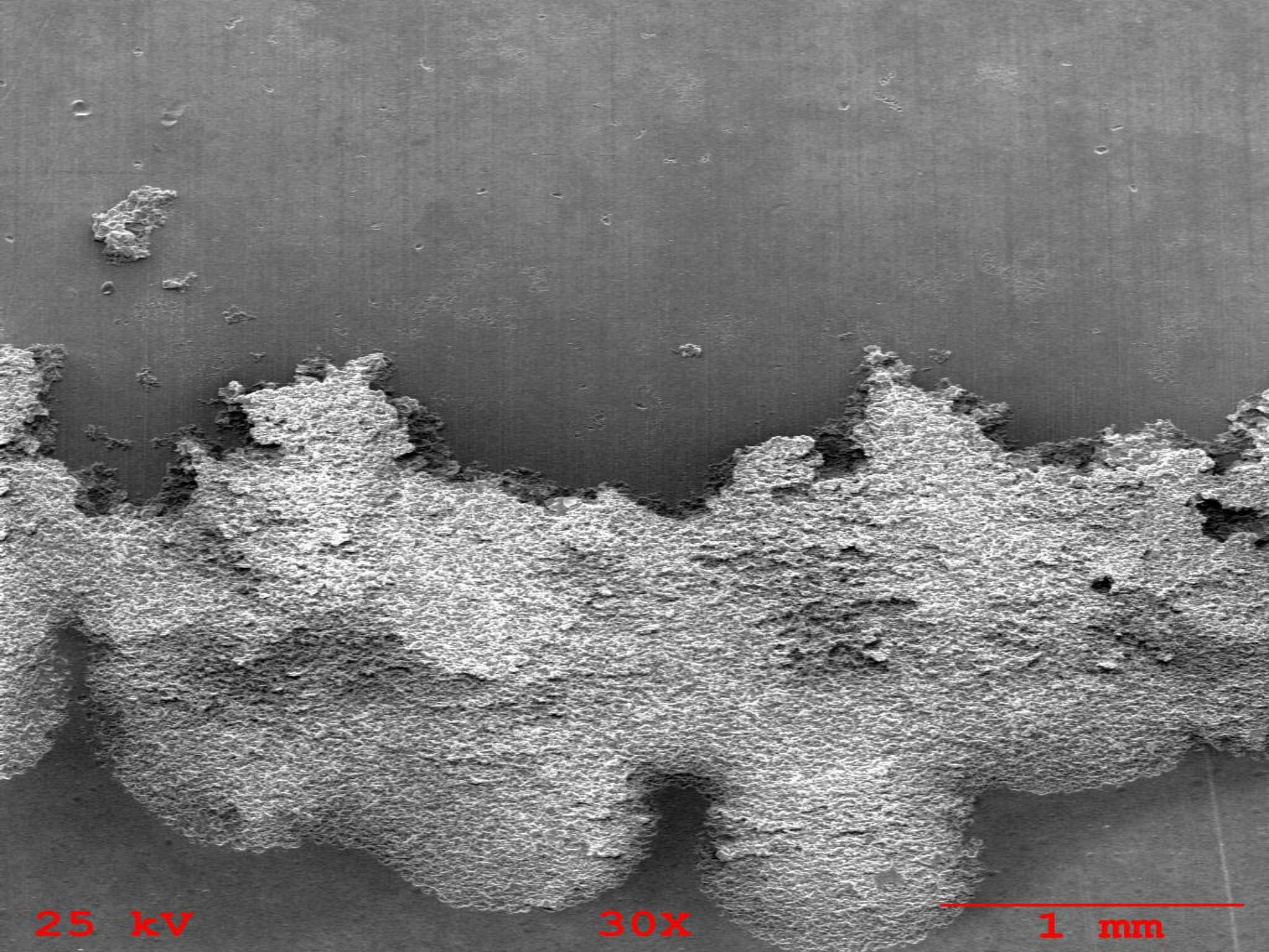
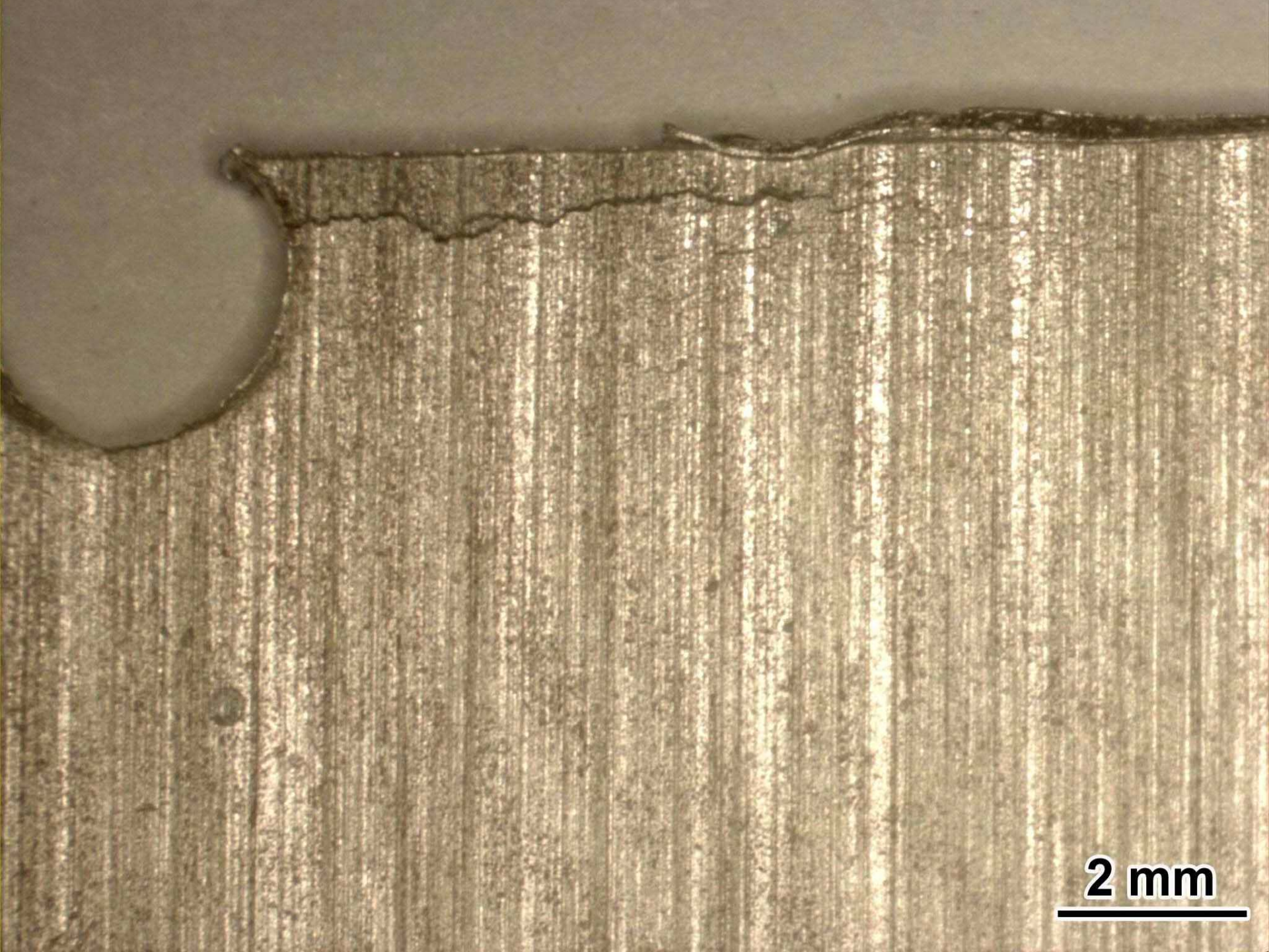
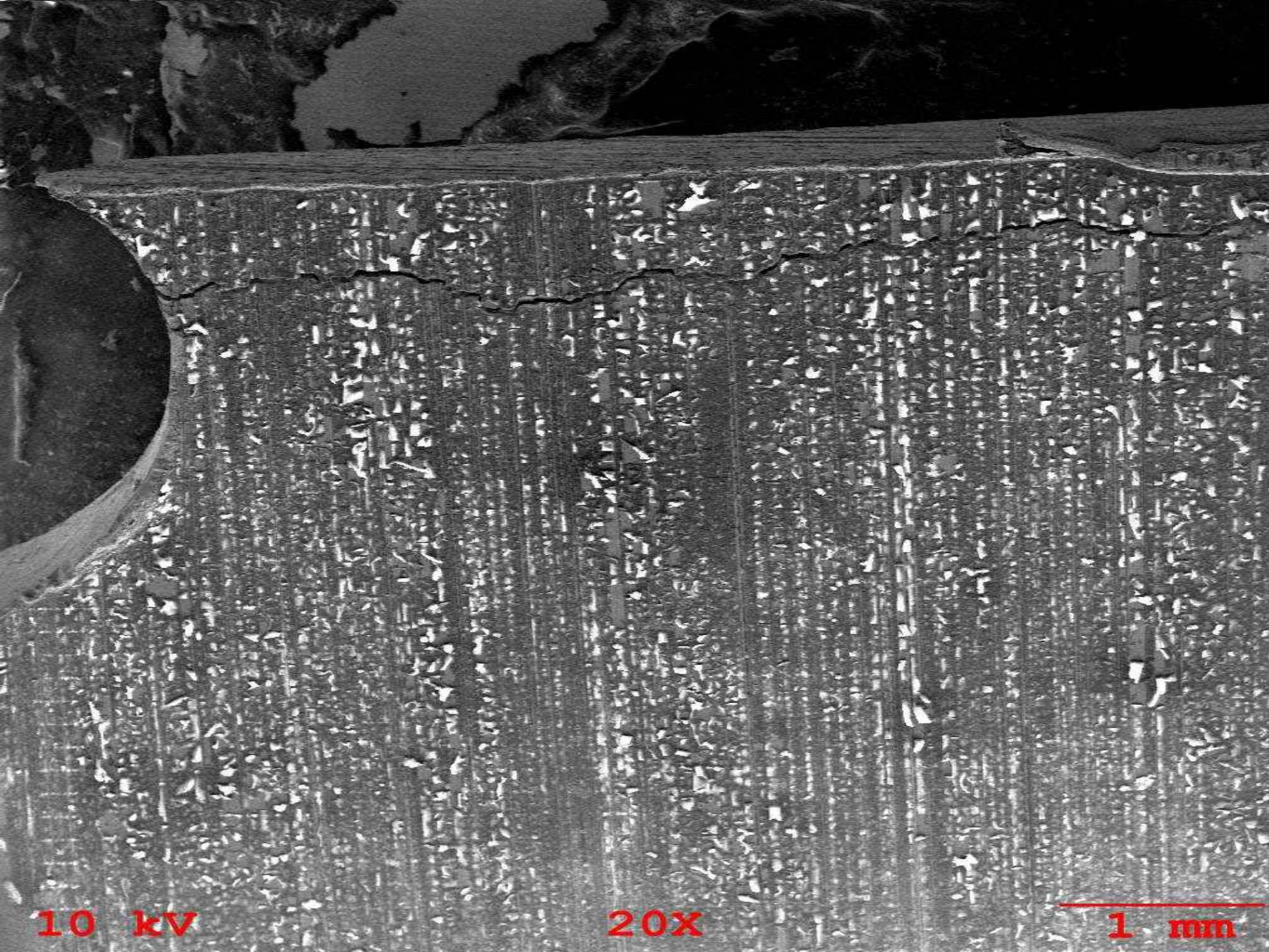
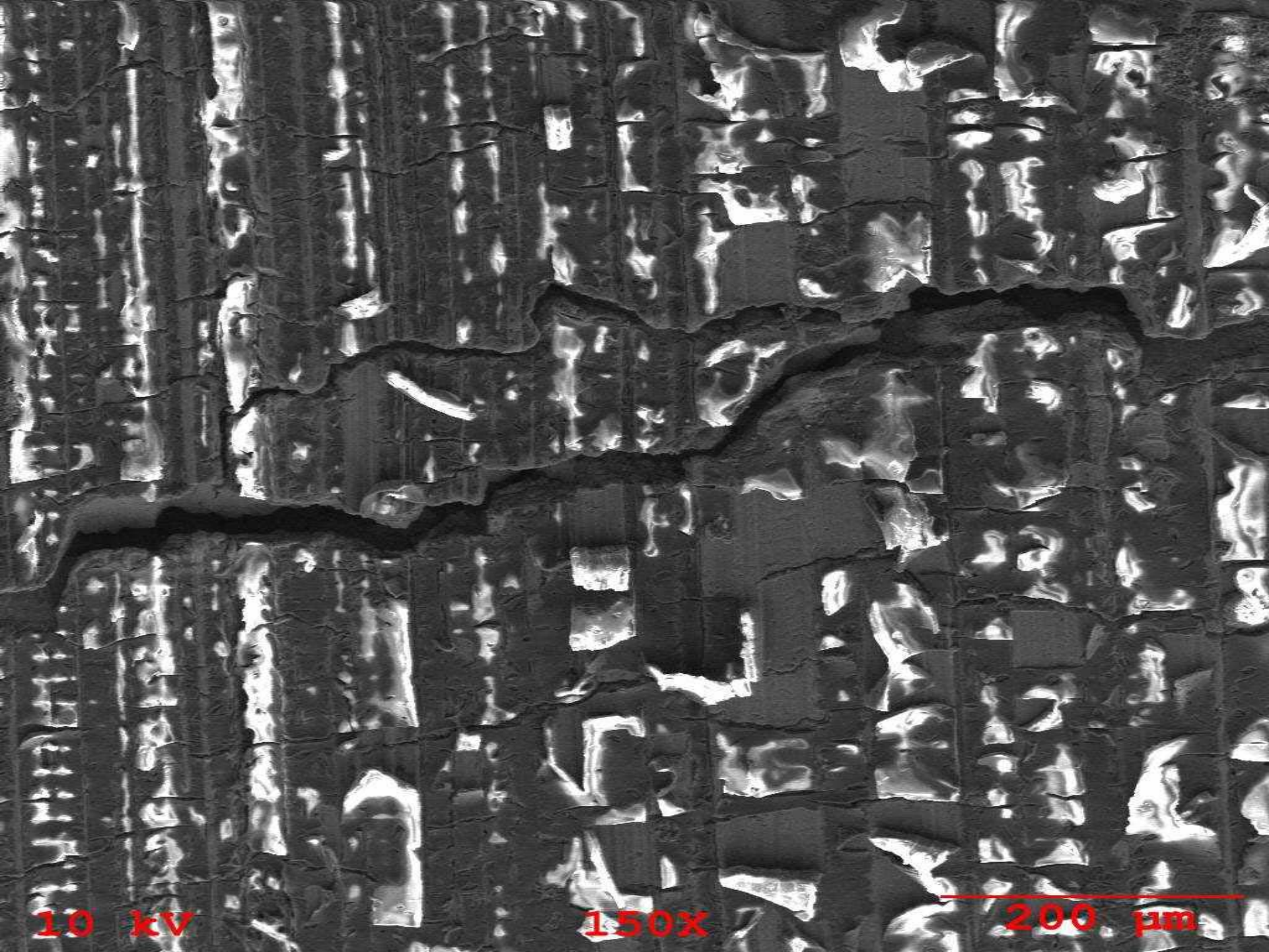
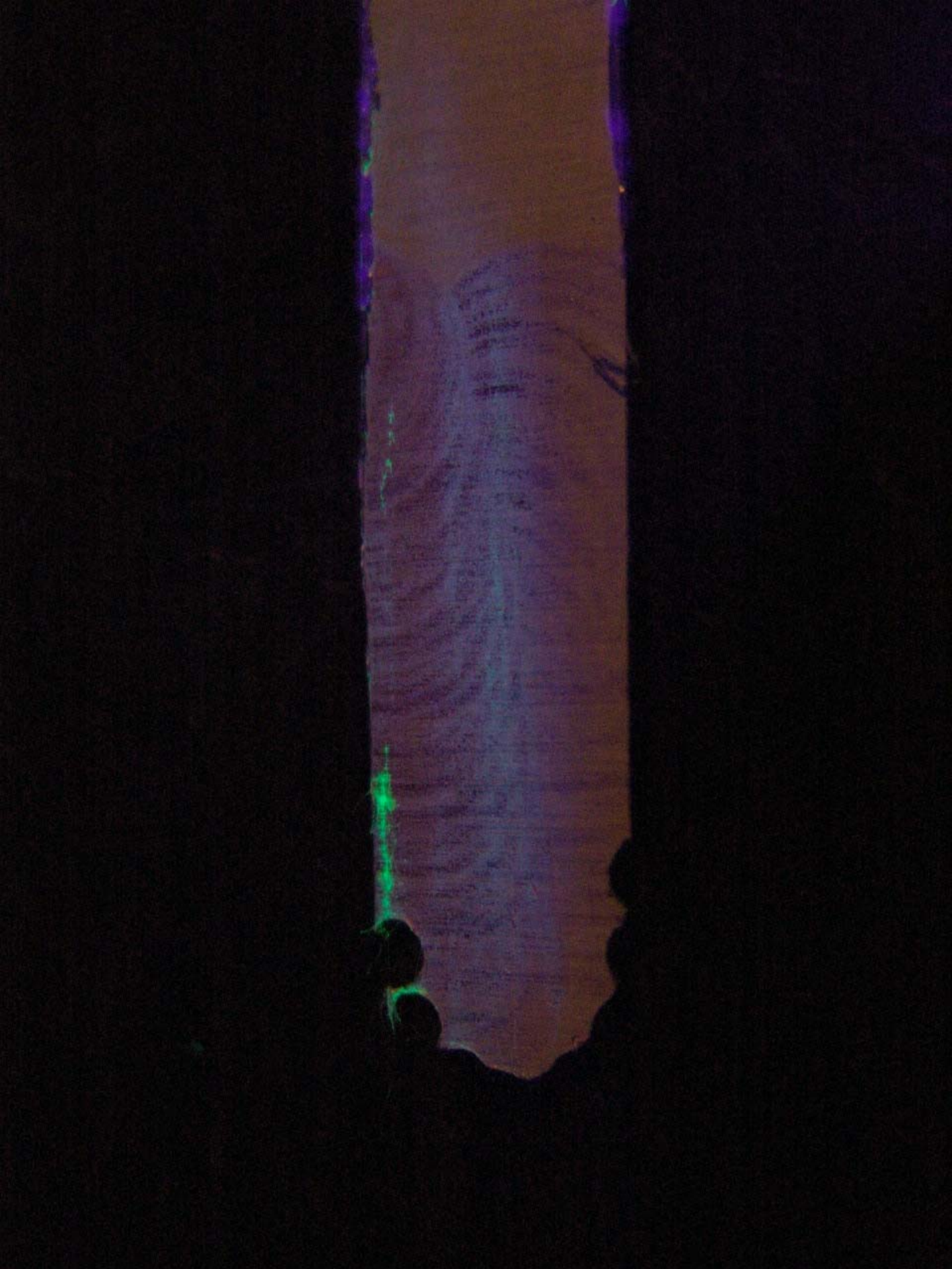
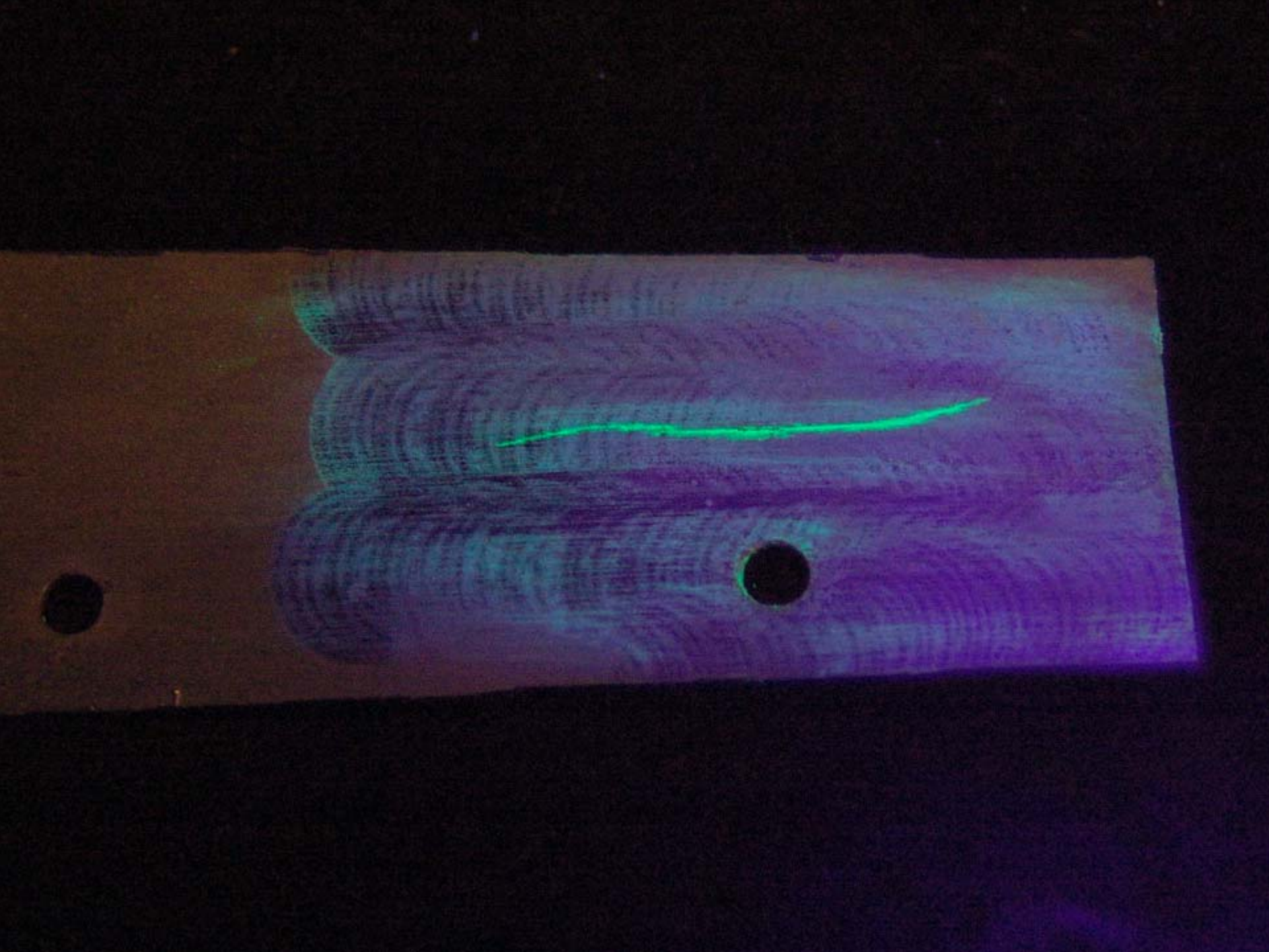

25 kV
30X
1 mm


2 mm


10 kV
20X
1 mm


10 kV
150X
200 µm





Surface Preparation for Bonding

Archive tests in support of Northrop F-18, F-35, B-2

- ***Application: Pre-bond surface prep of titanium, aluminum, and composite surfaces***
- ***Technique: Inter-laminar shear testing***
- ***Results and conclusions:***
  - ***Bond strength equivalent to any other process***
  - ***Trial-to-trial deviations almost zero***
  - ***"Eliminates the human error factor in aircraft manufacture" - Doris Reis, Senior F-35 M&P Engineer***
  - ***Significant environmental impact reductions***
  - ***Worker health and safety benefits***

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Substrate Damage Studies

- ***1989 - 1995 - US Navy, USAF***
- ***1995 - 1999 - EPA/NASA/USAF: Burlingame***
  - *"Very clean"*
  - *"Surface erosion - minimal"*
- ***More recent laser qualification programs***
  - *AFRL - JGPP laser system qualifications*
  - *NCMS / CTMA rotorblade depaint evaluation*
  - *FAA/GLC MA4872 evaluation for commercial aircraft*

GLC Material Tests for FAA

0.8 mm thick 2024 T3 Al Clad

Parameter	Results
1. Peak surface temperature measured during stripping	130 to 150°C = no metallurgical impact
2. Microstructure analyzed before and after stripping	No change in properties
3. Microhardness measured before and after stripping	No change in properties
4. Microscopic surface texture measured after stripping	Texture effects in soft clad layer only
5. SAE MA-4872 fatigue life tested after 5 x laser stripping and repainting	Equivalent fatigue life Process approved by FAA for use on commercial aircraft

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Environmental Impacts

- ***Surface ejecta:***
  - ***Metal oxide and dust particulate***
  - ***Oxidized hydrocarbons (CO_2, H_2O)***
  - ***Minimal un-oxidized hydrocarbons***
- ***Integral fume extraction entrains <u>all</u> waste – no surface residuals***
- ***HEPA filter for particle collection***
- ***Vapor discharge below action levels***

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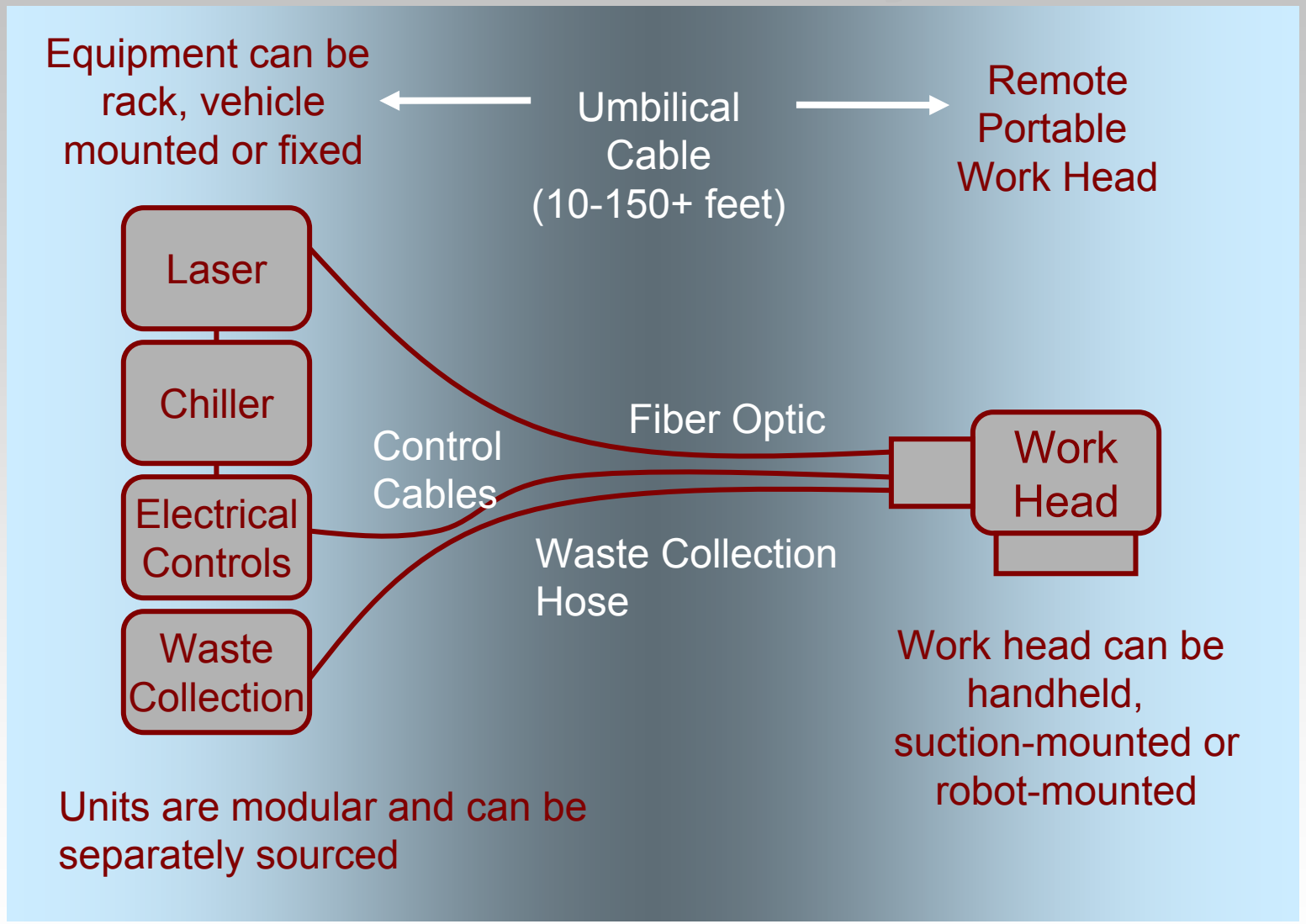
Laser Ablation System



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Color Recognition of Layers

- *USAF & Lockheed Martin coordinated support of F-22 SBIR*
- *Goal: Replace hand sanding for LO coating maintenance*
- *Phase I - 2001, Phase II- 2002 - 2004, US Patent Application - 2004*

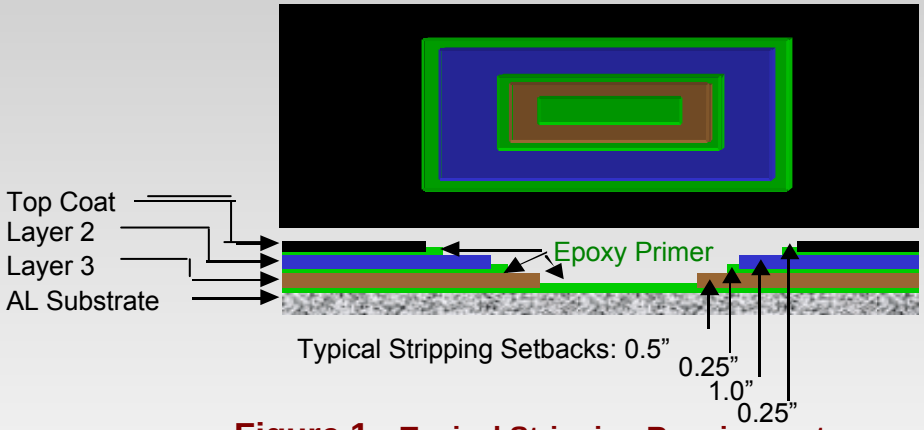

Figure 1 - Typical Stripping Requirements

Figure 2 - Actual Stripped Sample

Figure 3 - SBIR- Developed Workhead

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Figure 1 - Current Rotor Blade Stripping at Cherry Point

Figure 2 - Example of Blade Sanding Damage

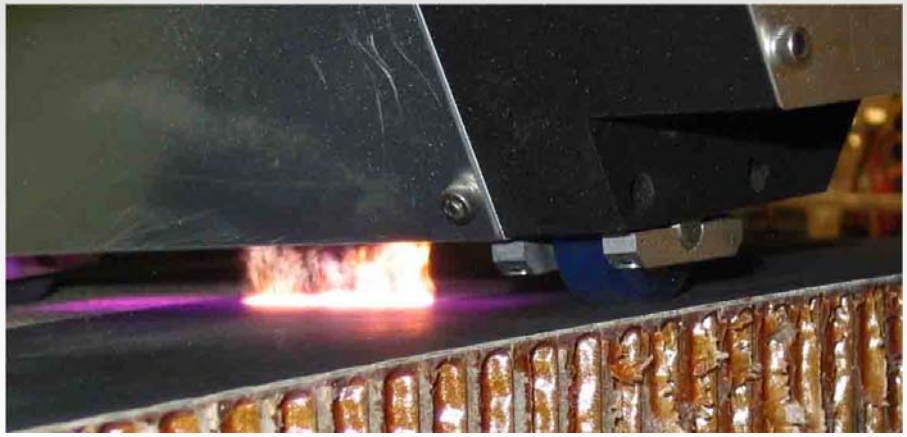

Figure 3 - Lasertronics Stripping Blade Sample

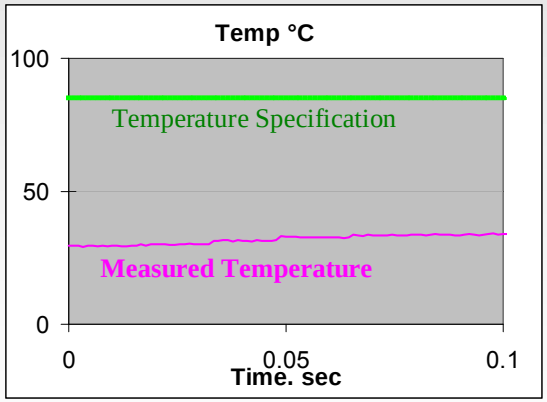

Figure 4 - Temperature during Laser Stripping

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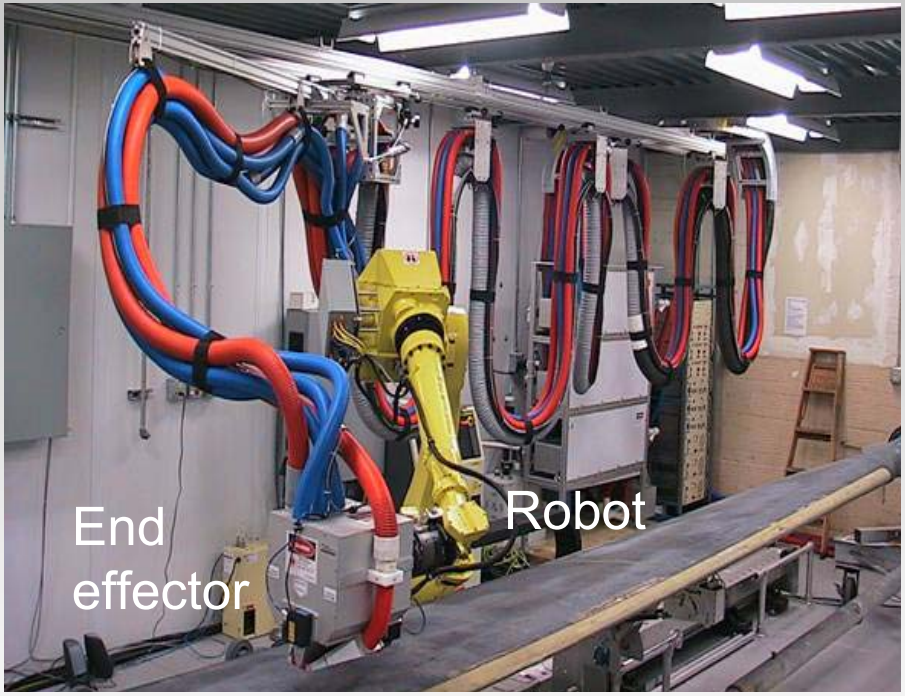
Defense Aerospace Installations



Automated rotorblade depaint,
Navy Fleet Readiness Center,
Cherry Point, NC

Hand-held system for
helicopter maintenance,
Patuxent River, MD

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Reliability / Maintainability

- **Extended Service:**
  - **April through September**
  - **90 hrs/wk operation**
  - **>2000 hours**
- **Reliability:**
  - **Described as “Workhorse”**
  - **No optics cleaning required**
  - **No OEM service required**
- **Maintainability:**
  - **Field personnel completed all maintenance**

Laser cleaning of thick corrosion layers from statuary on the City Hall of Philadelphia, PA

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